TITLE
ASP Conference Series, Vol. **VOLUME***, **YEAR OF PUBLICATION**
NAMES OF EDITORS

LIFTS: an Imaging Fourier Transform Spectrograph for Astronomy

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Abstract. We present the first astronomical observations of the Livermore Imaging Fourier Transform Spectrograph for visible-band astronomy using the 3.5-meter Apache Point Observatory.

1. Introduction

We present the first astronomical results of LIFTS (see Wurtz et al. 2001 for details). The double output Michelson interferometer allow the observation of a spectrum for each of the 1k x 1k pixels of the combined images.

In a collimated beam, the incoming light hits a beam splitter and follows two possible optical paths before recombining into two output CCD cameras. All the photons are therefore contained in the sum of the two images while the relative phase shift information is stored in their difference. When stepping through a range of path length differences, by moving one arm of the interferometer, one ends up with the Fourier transform of the spectrum for each element of the images.

1.1. The Unique Advantages of an IFTS

By first principles, an FTS has a highly flexible resolution from $\mathcal{R} = 1$ to several thousands, only limited by the maximum travel of the moving arm (1 cm in our case). Every pixel contains a spectrum, and all the images can be co-added to obtain a very deep image, called the "panchromatic" image. Follow-up spectroscopy of faint objects discovered in the panchromatic image can be directly obtained from the datacube. The observer can even decide to increase the spectral resolution in real-time by increasing the number of steps to a higher path length difference. We stress that this technique does not require preselecting objects or subregions in a few-arcminute field to be fed to a spectrograph.

Compared to any dispersive system, where all the spatial and spectral elements have to fit on a single CCD, the IFTS has a substantial multiplex advan-

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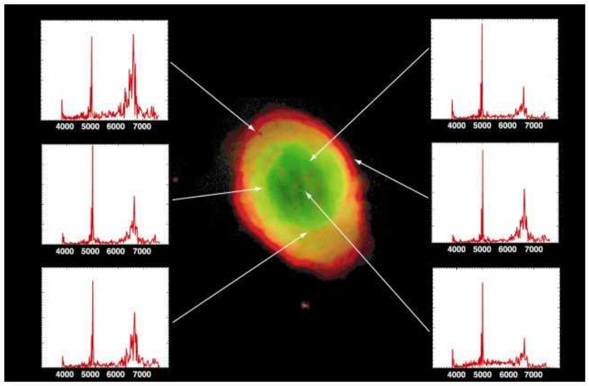

Figure 1. A view of a spectral-spatial datacube of the Ring Nebula, obtained with LIFTS at Apache Point Observatory. The figure shows the panchromatic image and the spectrum of representative pixels.

tage. Not only is the full CCD available for spatial information, but the spectral information is just limited by the number of channels one is willing to take on a given field. This multiplex advantage is proportional to the density of relevant pixels in the image (including some amount of sky and calibration objects).

The IFTS must be distinguished from filter systems including imaging Fabry-Perot (FP) spectrographs or tunable filters. An IFTS accept all the light at all wavelengths. It only creates one interference between the two "branches" of a photon and records the phase difference. On the other hand, an FP creates multiple "branches" by multiple reflections inside a cavity creating constructive interferences only for a narrow band of wavelengths, rejecting most of the light. Also, the passband is periodic and one order has to be selected, limiting the spectral range to a few angstroms. F-P systems are better suited for narrow band observations of faint extended objects as they cut all the out-of-band noise to which IFTS would be sensitive.

2. Observations with the Livermore IFTS

We have had a total of seven clear bright-time half-nights on the APO 3.5-meter with the completed instrument. Seeing ranged from 0.7 to 1.5 arcsec, so we binned to 512 pixels so that our pixel size was 0.28 arcsec. The Ring Nebula datacube, at $\mathcal{R} \sim 430$, is presented in Figure 1.

References

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